

In-Situ Chemical Reduction and Oxidation of VOCs in Groundwater

**Groundwater
Treatability Studies**

**NASA
Marshall Space
Flight Center
Huntsville, Alabama
June 2001**

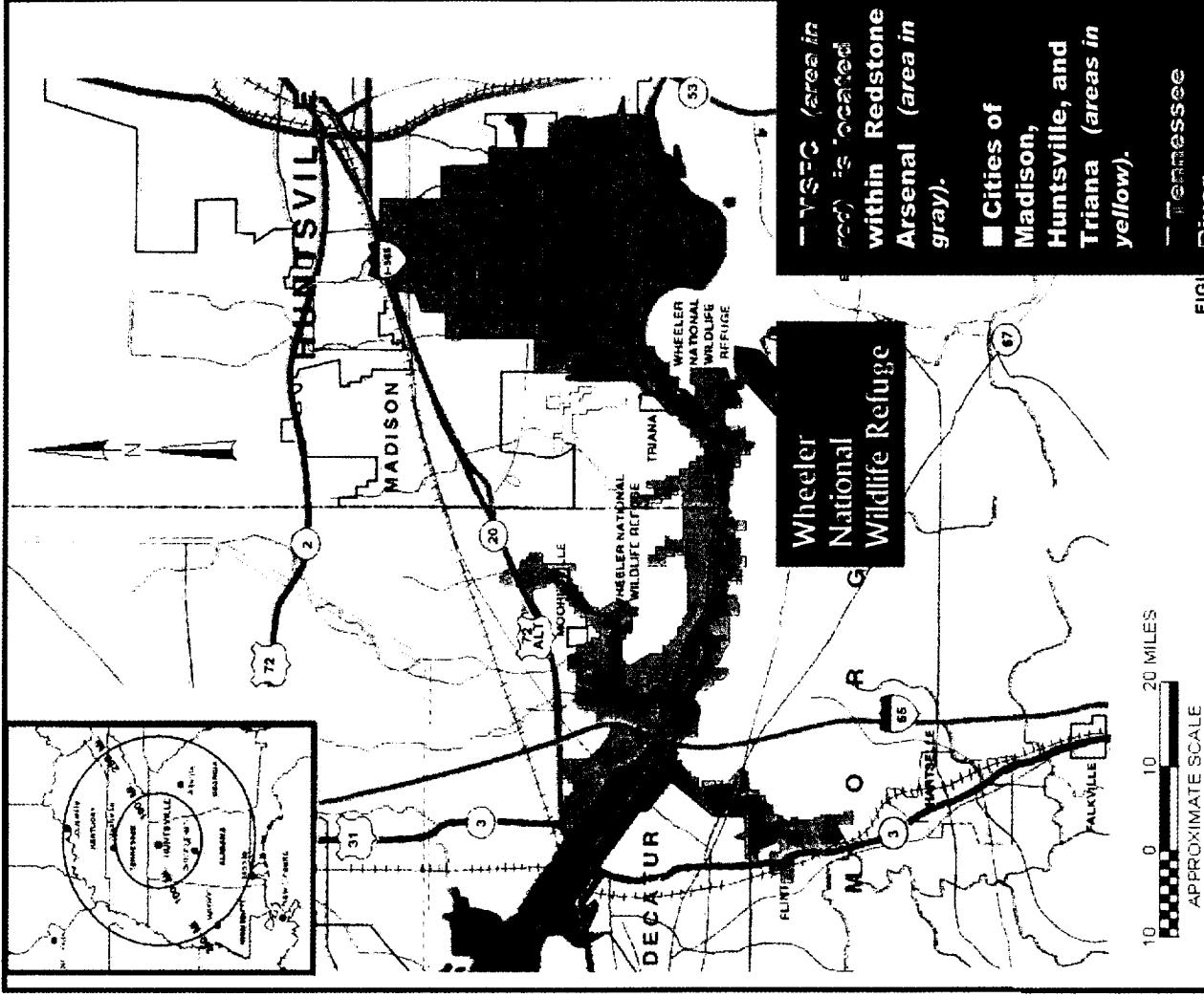
presented by Amy Keith, MSTECH ED



Marshall CERCLA Program Overview

- Located within Redstone Arsenal.
- Marshall listed on the NPL (as a Superfund Site) - May 31, 1994.
- 65-70 sites are Marshall's responsibility.

00-25-02 1200-44 5-04 SITE-A.COR

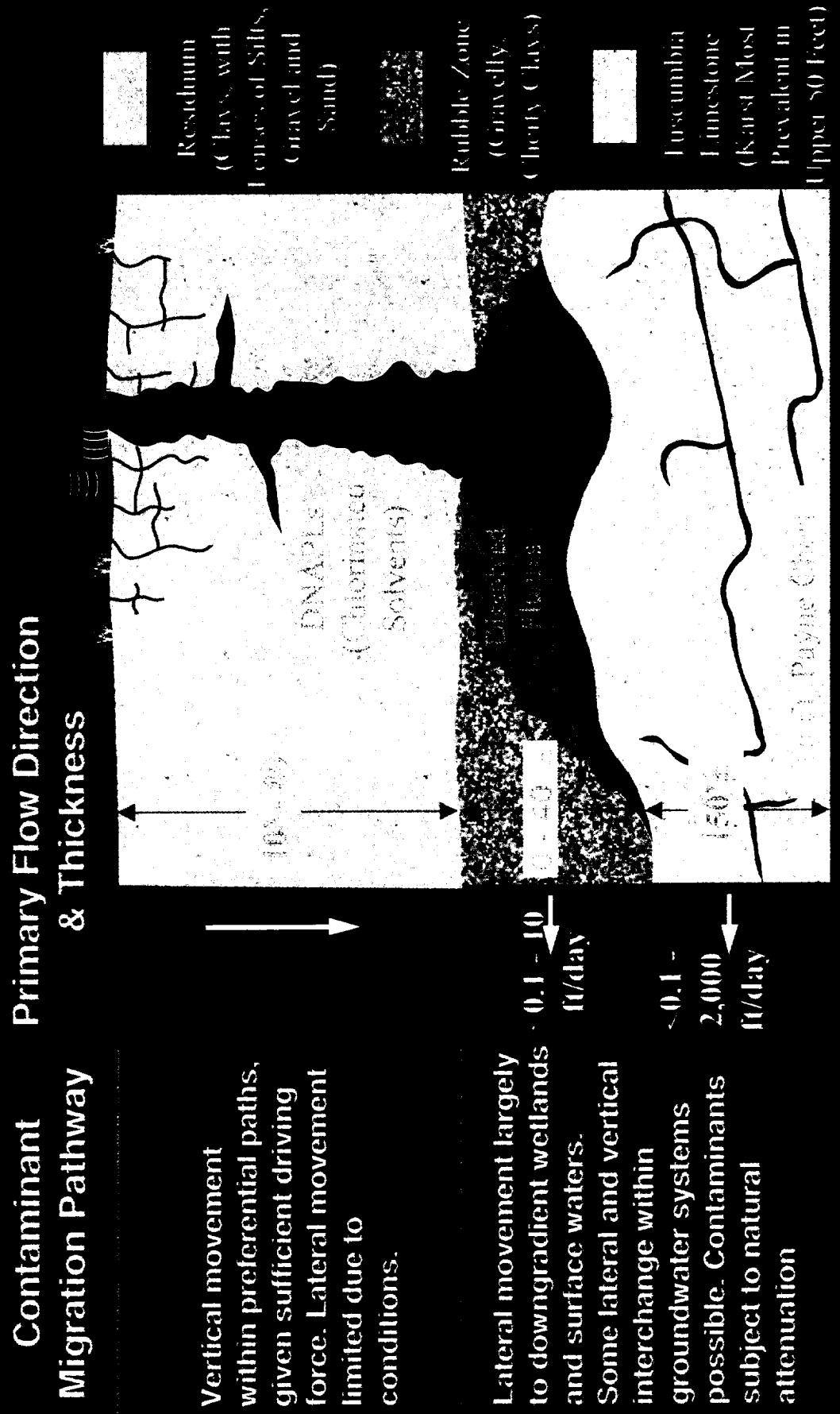


Marshall Center Quick Facts

- Originally used for manufacturing munitions during WWII.
- 1949: RSA mission to develop rocketry and guided missile systems.
- 1960: Civilian rocketry and mission activities transferred to NASA.
 - Mercury through Apollo Program
 - Space Shuttle Main Engine Development
 - X-33 Program
 - International Space Station



Site Conceptual Model (Epikarst and Karst System)



Marshall Center CERCLA Groundwater Strategy

*Thermal image
map of MSFC.*



- **Identify Potential Exposure Locations**
- **Eliminate / Reduce Rubble Zone Source Areas.**
- **Monitor to Verify Effectiveness of Treatment Actions.**
- **Monitor to Verify Continued Compliance With ARARs**
- **Contingency Plan for Spring (GW discharge points) in Case of Risk Exceedance**

Treatability Studies

**Treatability Results Will be
Used to Prepare a Feasibility
Study (late 2002)**

**Proposed In-Situ Groundwater
Treatment Technologies
Include**

Chemical Reduction (FeroxSM)

**Chemical Oxidation (Fenton
Reagents, Permanganate, and
Persulfate)**

**Thermal (Dynamic Underground
Stripping, Six-Phase Heating)**

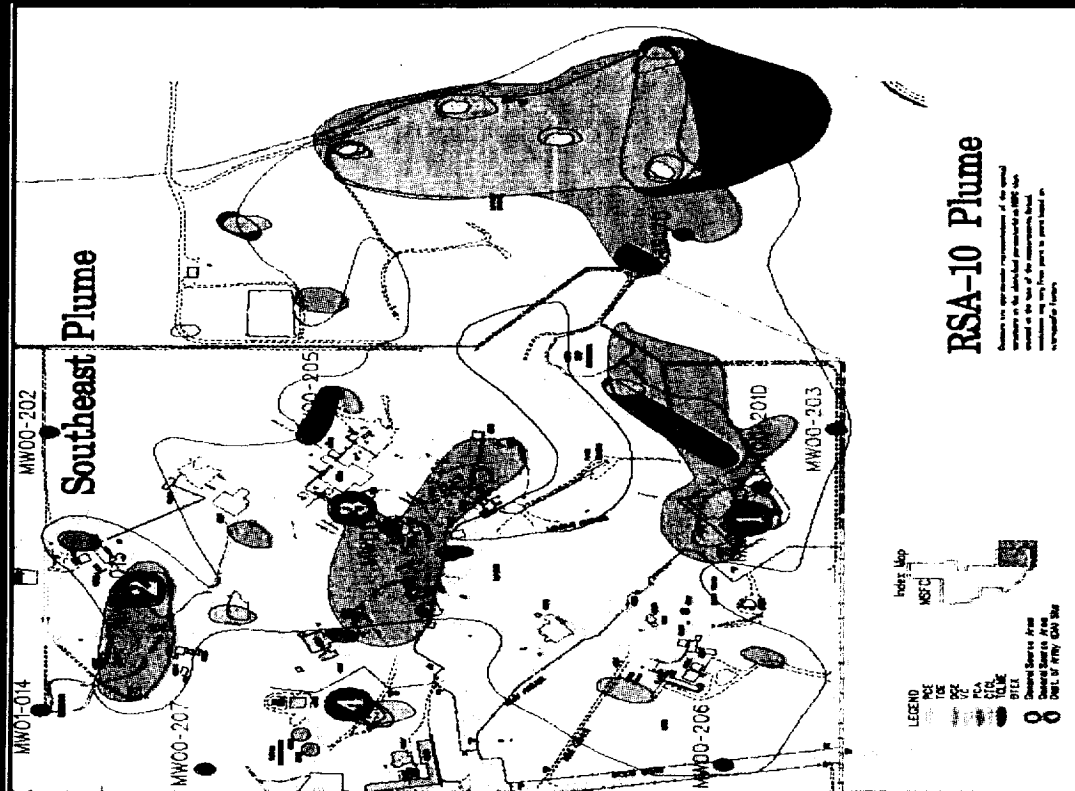


Source Area 2 Site Description

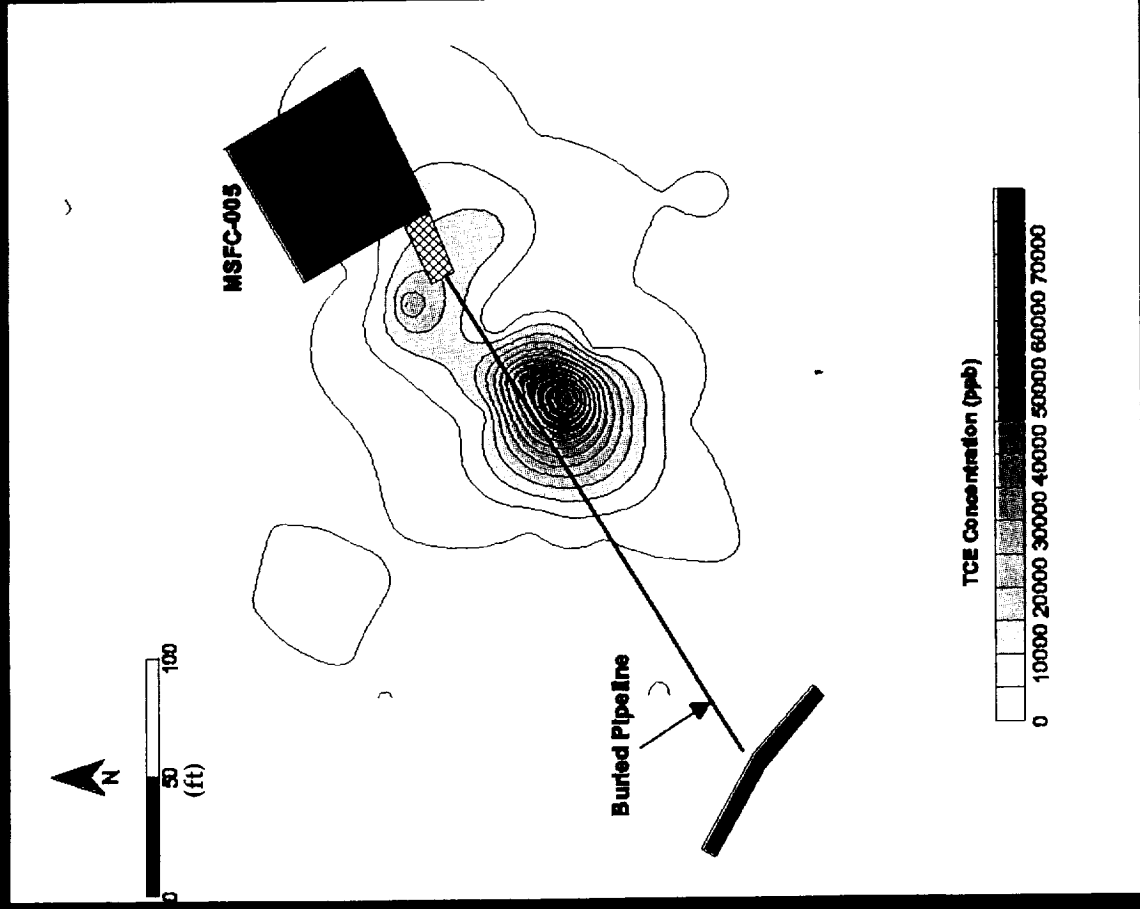
SA-2 (MSFC-005) is a pond that received TCE from engine cleaning operations

TCE is no longer used at the site; no continuing source

Dissolved phase TCE and DCE reported in the groundwater



Source Area 2 Groundwater and Subsurface Characteristics



UXO is potentially buried beneath the surface

The highest reported TCE concentration in the rubble zone groundwater is 72,800 $\mu\text{g/L}$

TCE was not detected in the vadose zone clays

Depth to bedrock varies from 22 ft to 34 ft

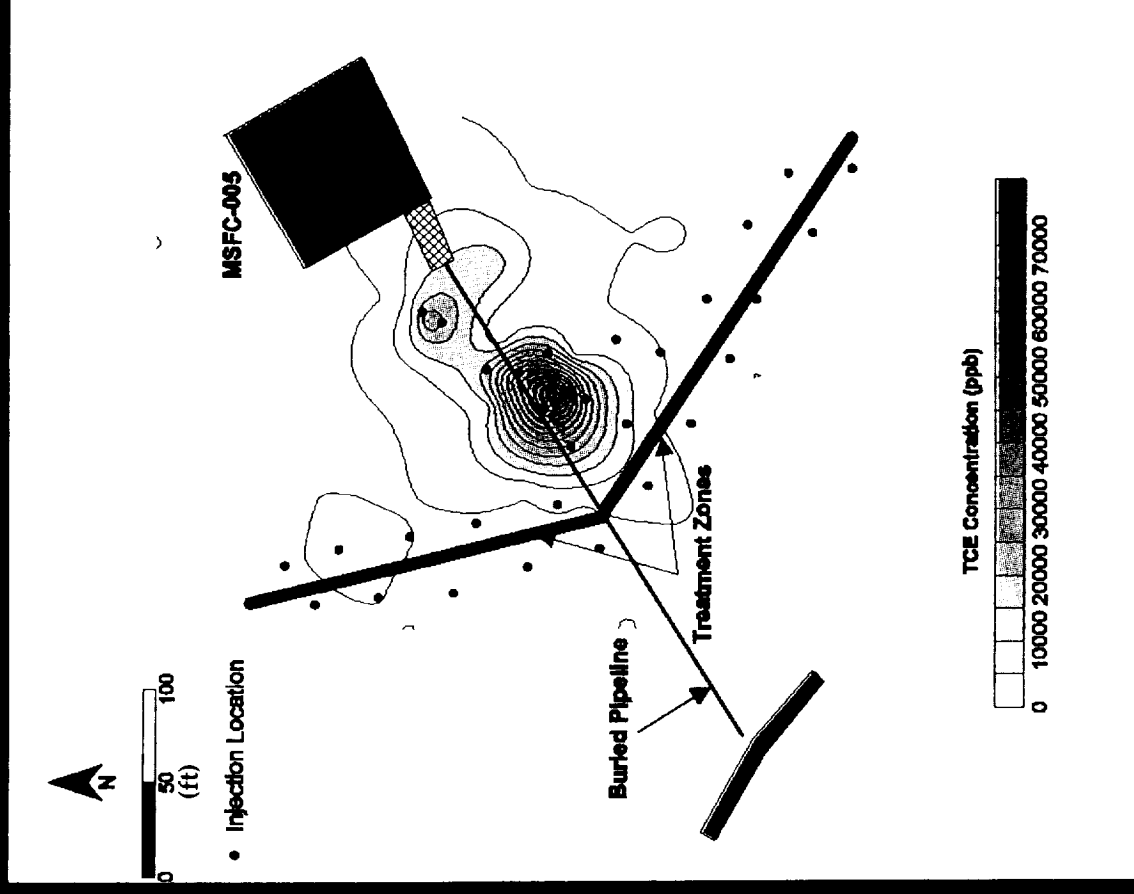
Rubble Zone Groundwater Characteristics

Groundwater velocity is 0.14 ft/day

Groundwater is aerobic (DO 5-7 mg/l)

Groundwater ORP is 130 mV

Source Area 2 Pilot Test Approach



Pneumatic Fracturing of
the rubble zone and soil
capillary zone

ZVI (FeroxSM) injections
in accessible TCE "Hot
Spots"

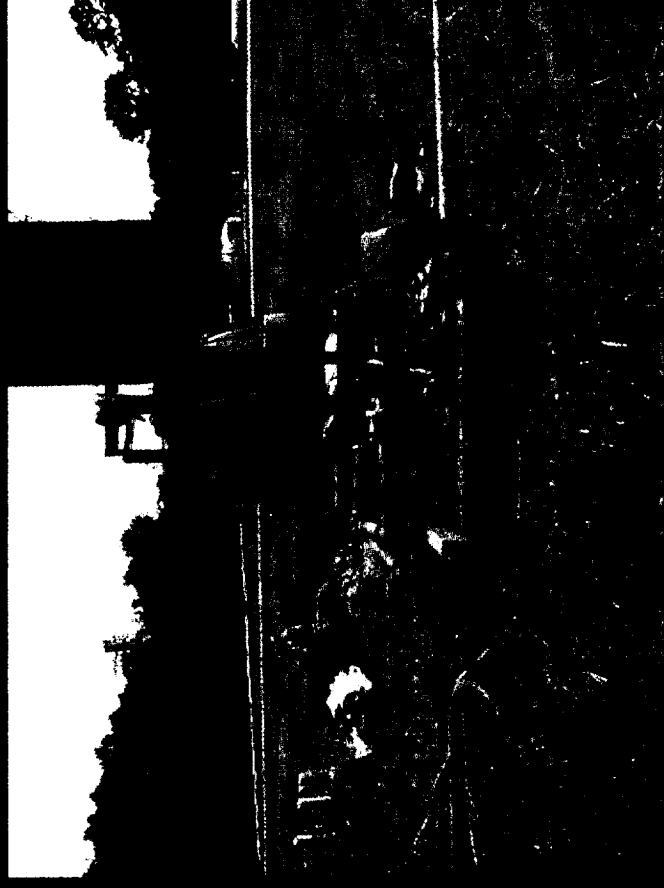
Create a ZVI permeable
reactive zone
downgradient from the
"Hot Spots"

Source Area 2 FeroxSM Injections

Nitrogen and Fracture Trailer

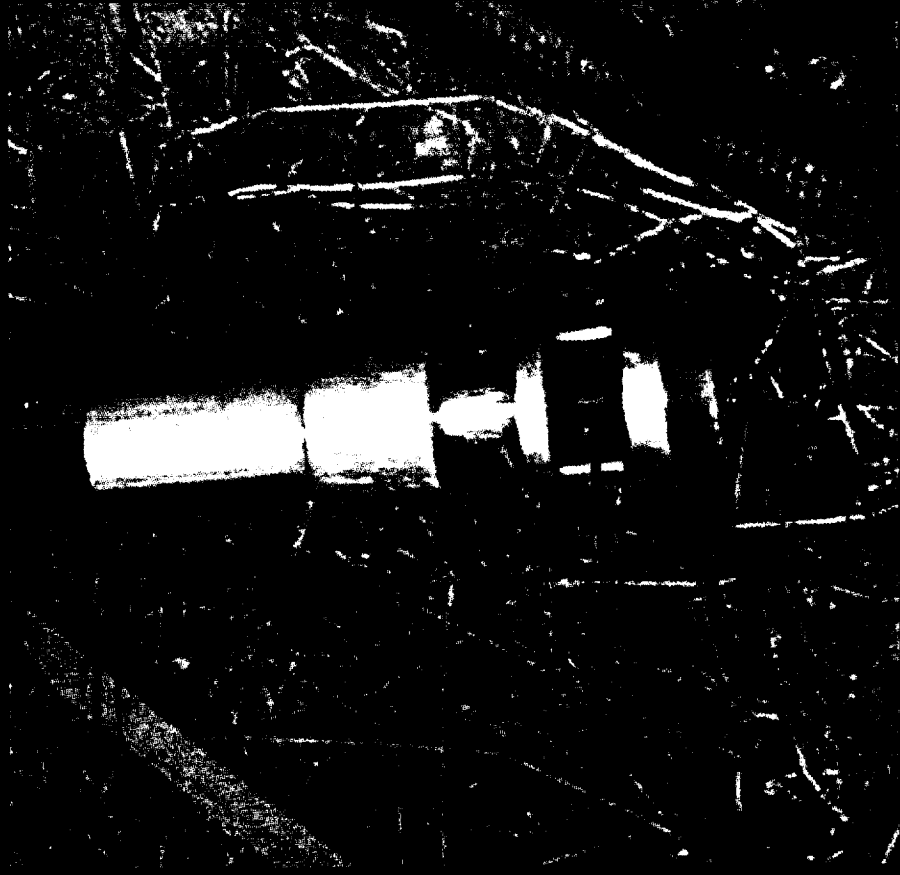
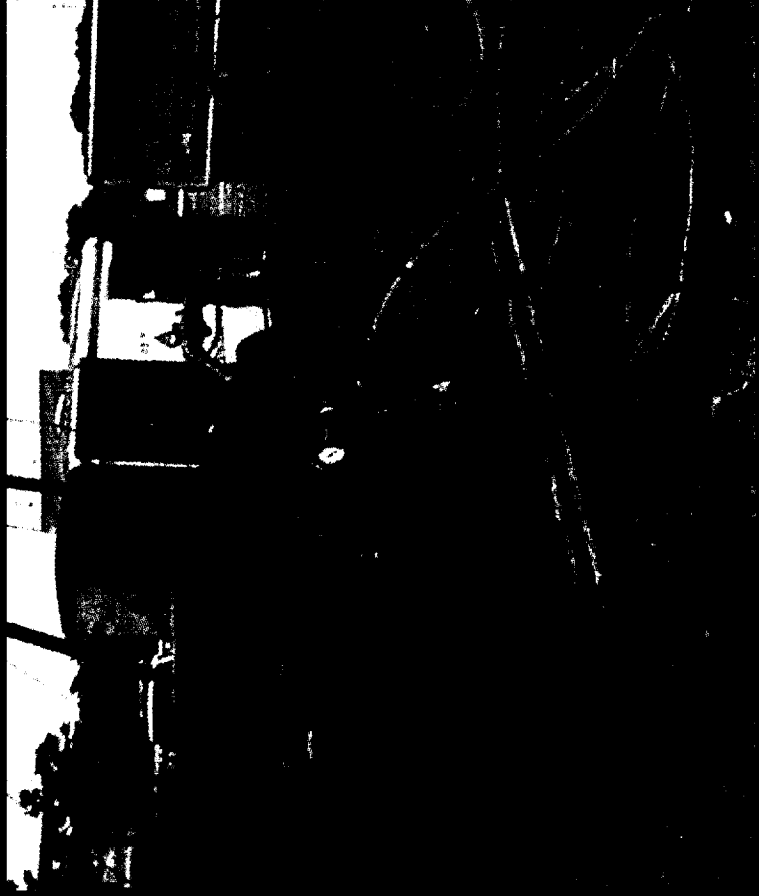


Iron Slurry



Source Area 2 FeroxSM Injections (continued)

Injector System Set Up 360° Injection Nozzle and Packer

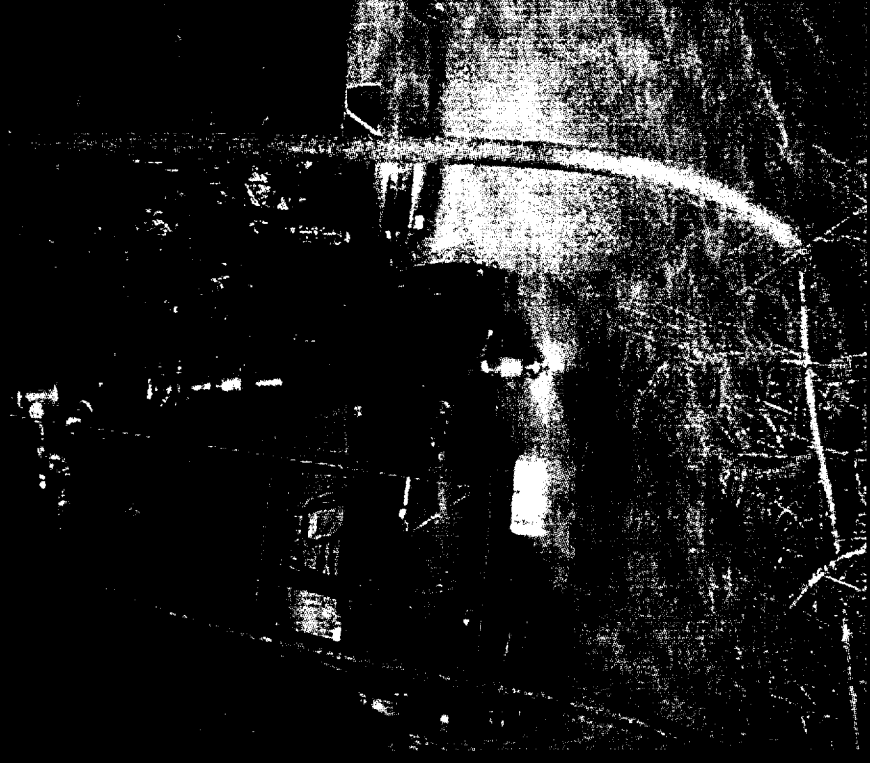


Source Area 2 FeroxSM Injections (continued)

Gravity Feed Injection



Atomized Injection



Note: Flow rate 5 gpm for both injections

Source Area 2 Pilot Test Results



11,000 lbs of ZVI was injected

An Iron to TCE ratio of 200:1 was established (from bench scale study)

Radius of influence was 20 to 60 ft

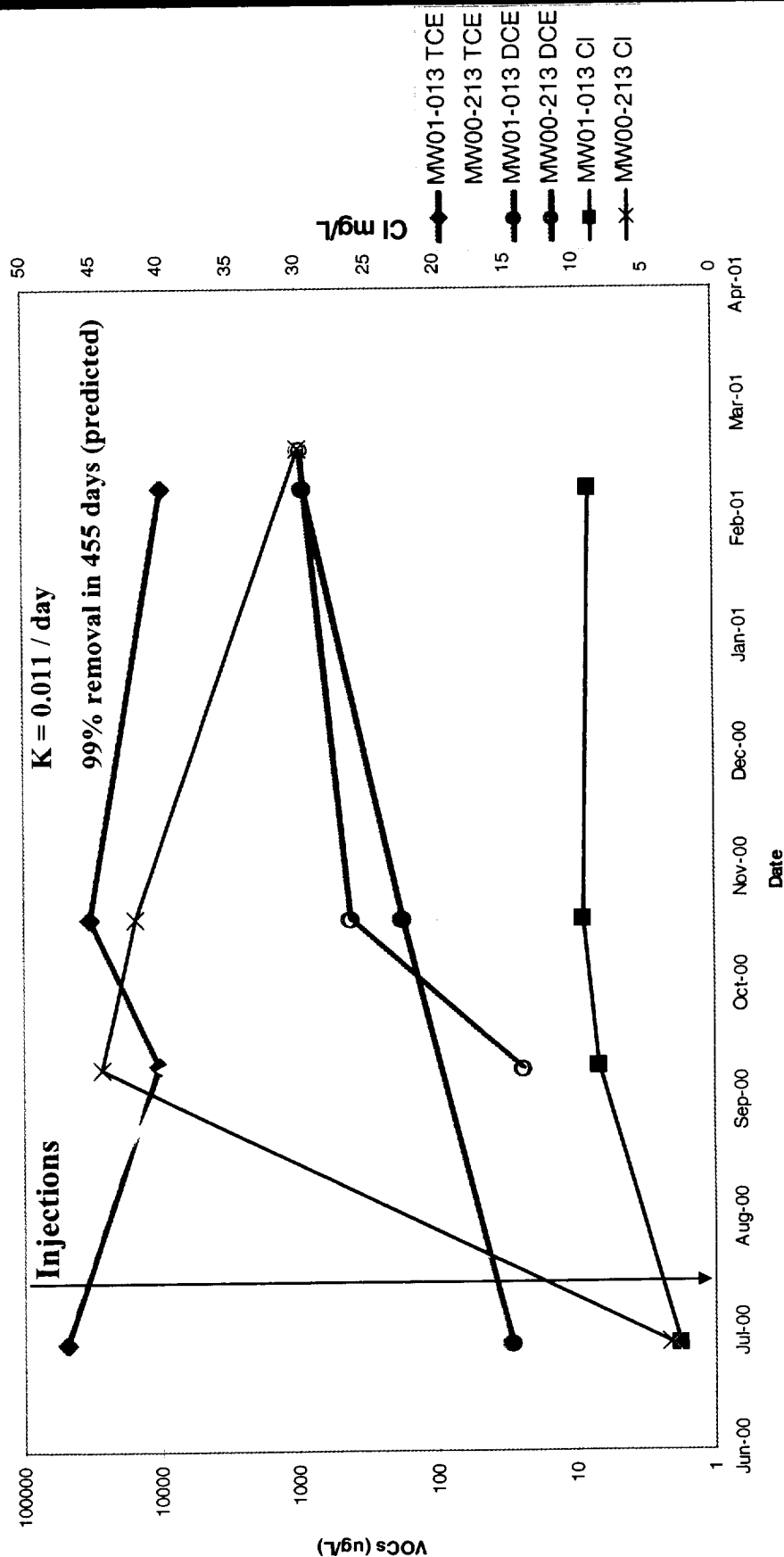
Iron impregnated the subsurface treatment zone

Average fracture initiation pressure was 120 psi

Average fracture propagation pressure was 60 psi

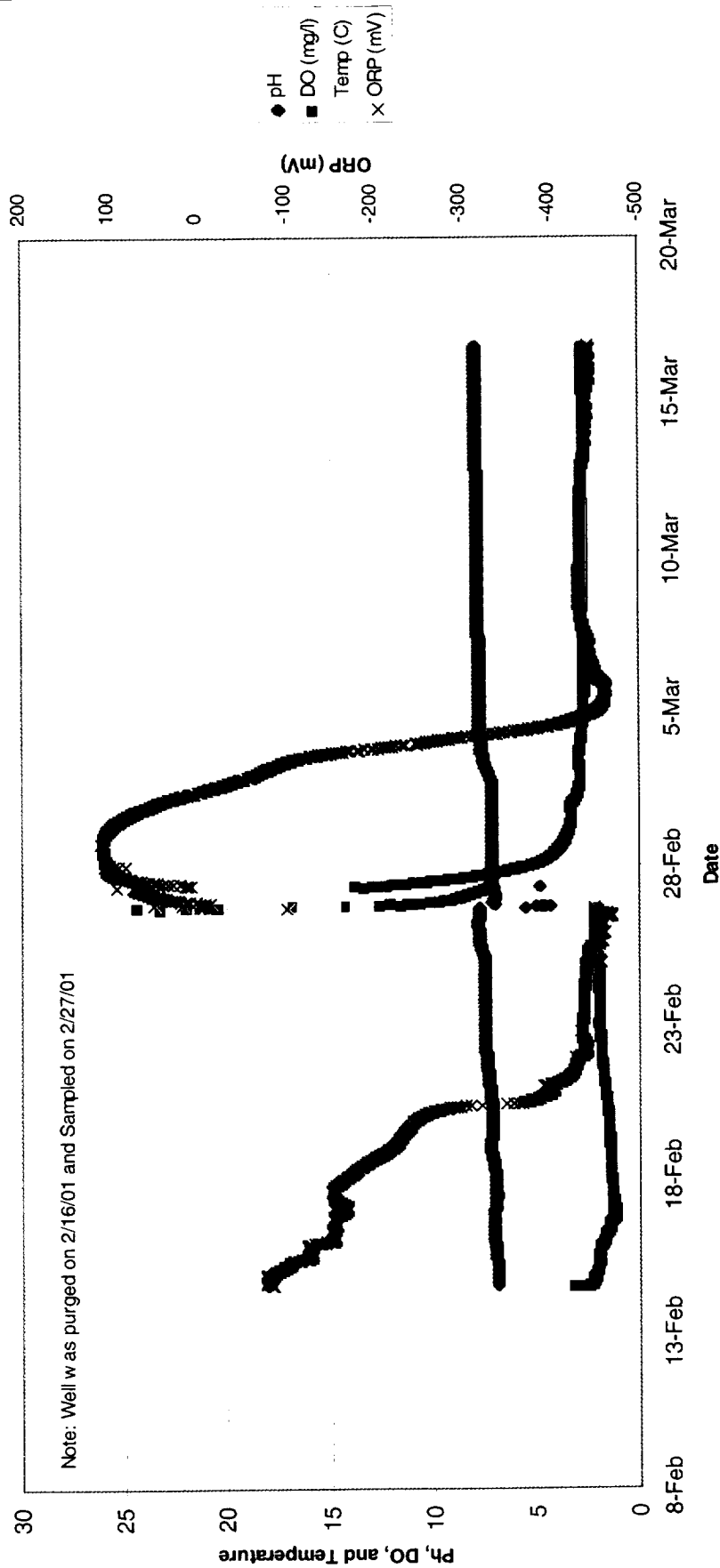
Source Area 2 Pilot Test Results - TCE Reduction, *cis*-1,2-DCE and Chloride Ion Formation

SA-2 Source Well VOC and Cl Concentrations vs Time



Source Area 2 Pilot Test Results - Aquifer Reducing Conditions

MW00-213 In-Situ Troll Data



SA-12 - Degreasing Operations Conducted

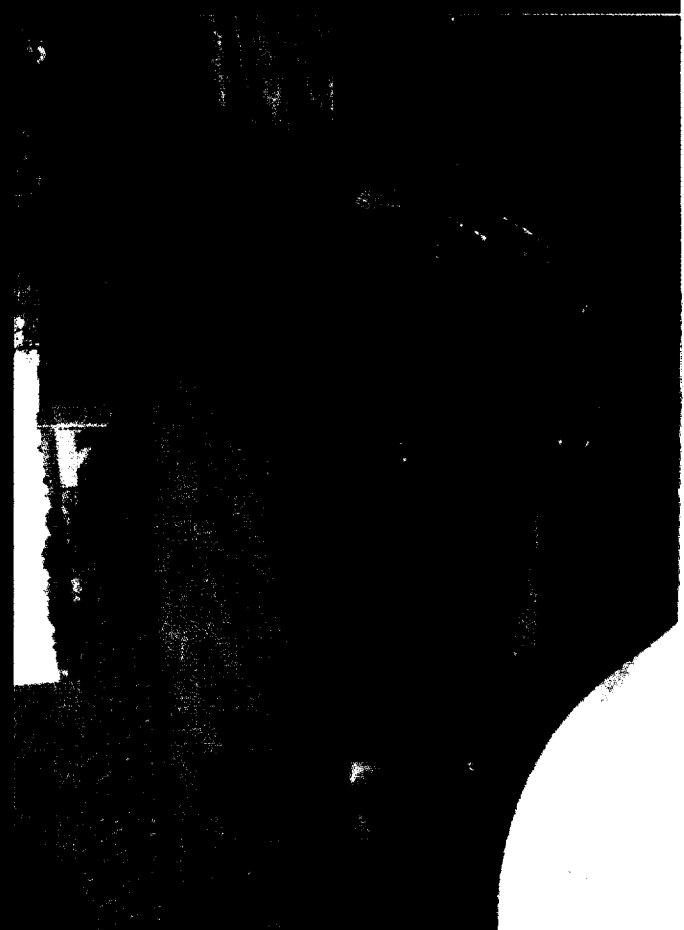
**TCE concentrations up to
500,000 µg/l**

Unexpected DNAPL Conditions

Rubble Zone Groundwater Characteristics

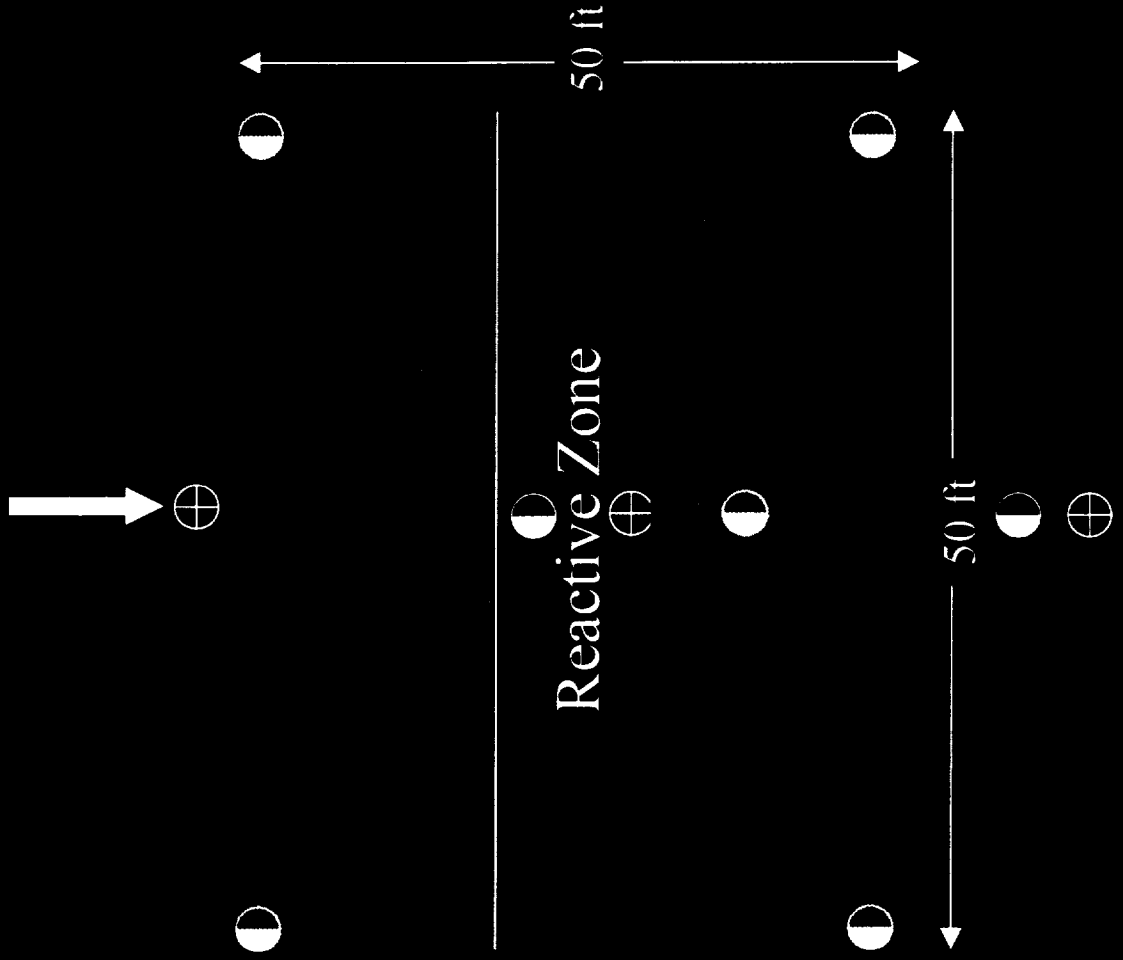
Groundwater velocity is 0.04 ft/day
Groundwater is aerobic (DO 5-7 mg/l)

Groundwater ORP around 130 mV



Source Area 12 Pilot Test Approach

Groundwater Flow Direction



Pneumatic Fracturing of the rubble and vadose zone and ZVI injections

Create a ZVI reactive zone 10 ft by 50 ft in the "Hot Spot" to treat the TCE

⊕ Monitoring Well 2-inches

⊕ Monitoring Well Cluster - Upper and Lower Rubble Zone

Source Area 12 Pilot Test Results



A total of 4,500 lbs of iron was injected in the subsurface

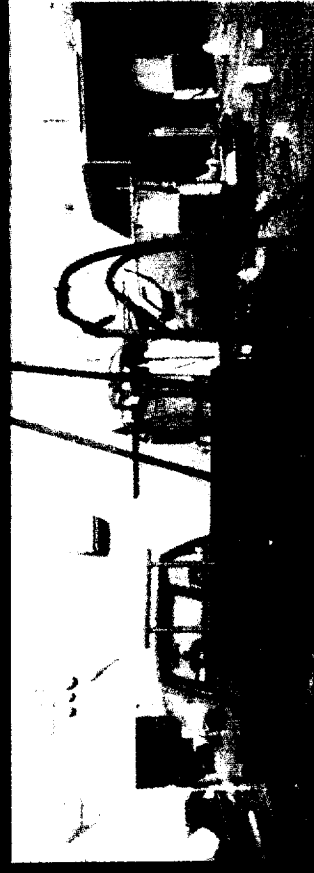
An Iron to TCE ratio of 100:1 was established

Radius of ZVI influence was about 20 ft

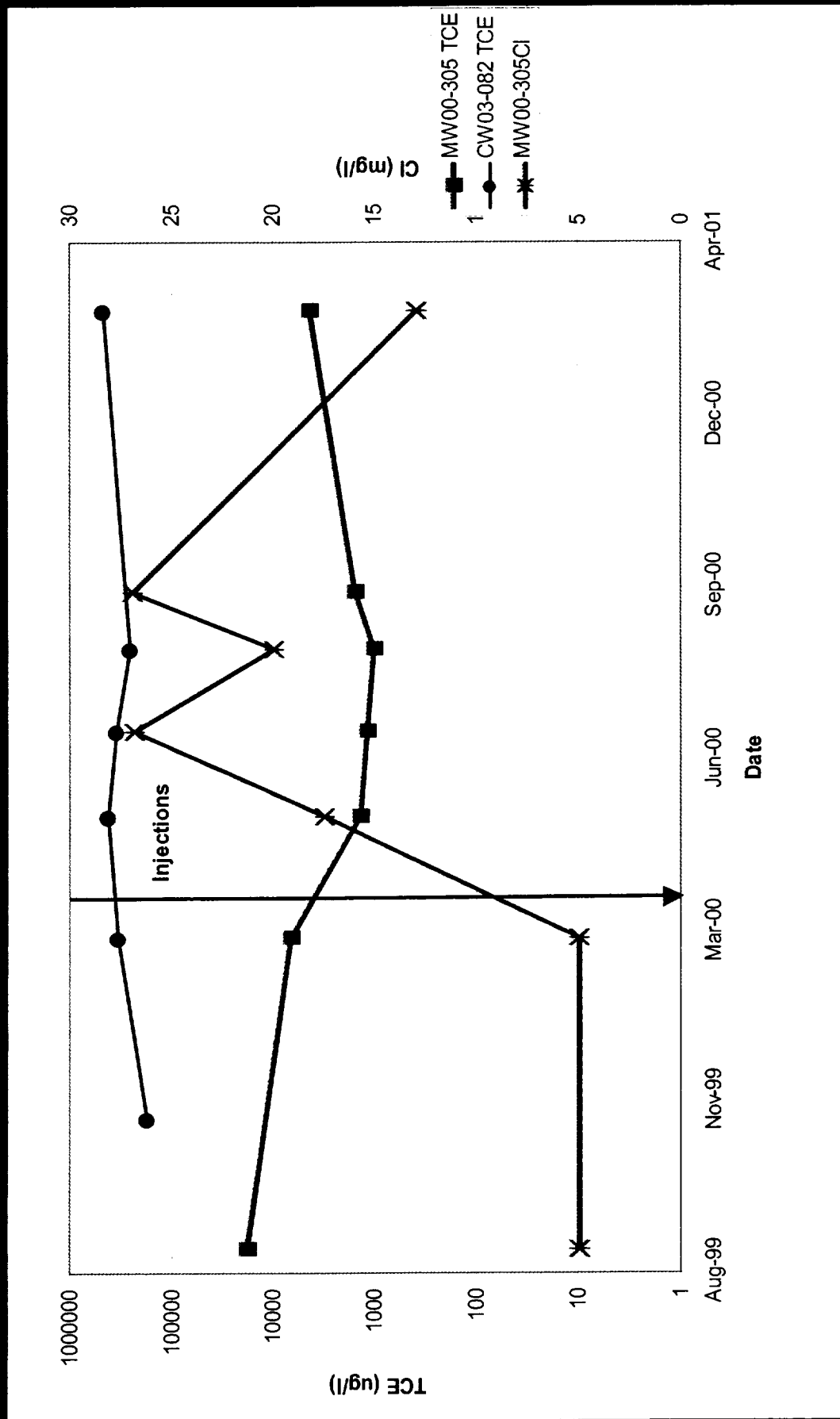
Iron impregnated the subsurface soil

Average fracture initiation pressure was 130 psi

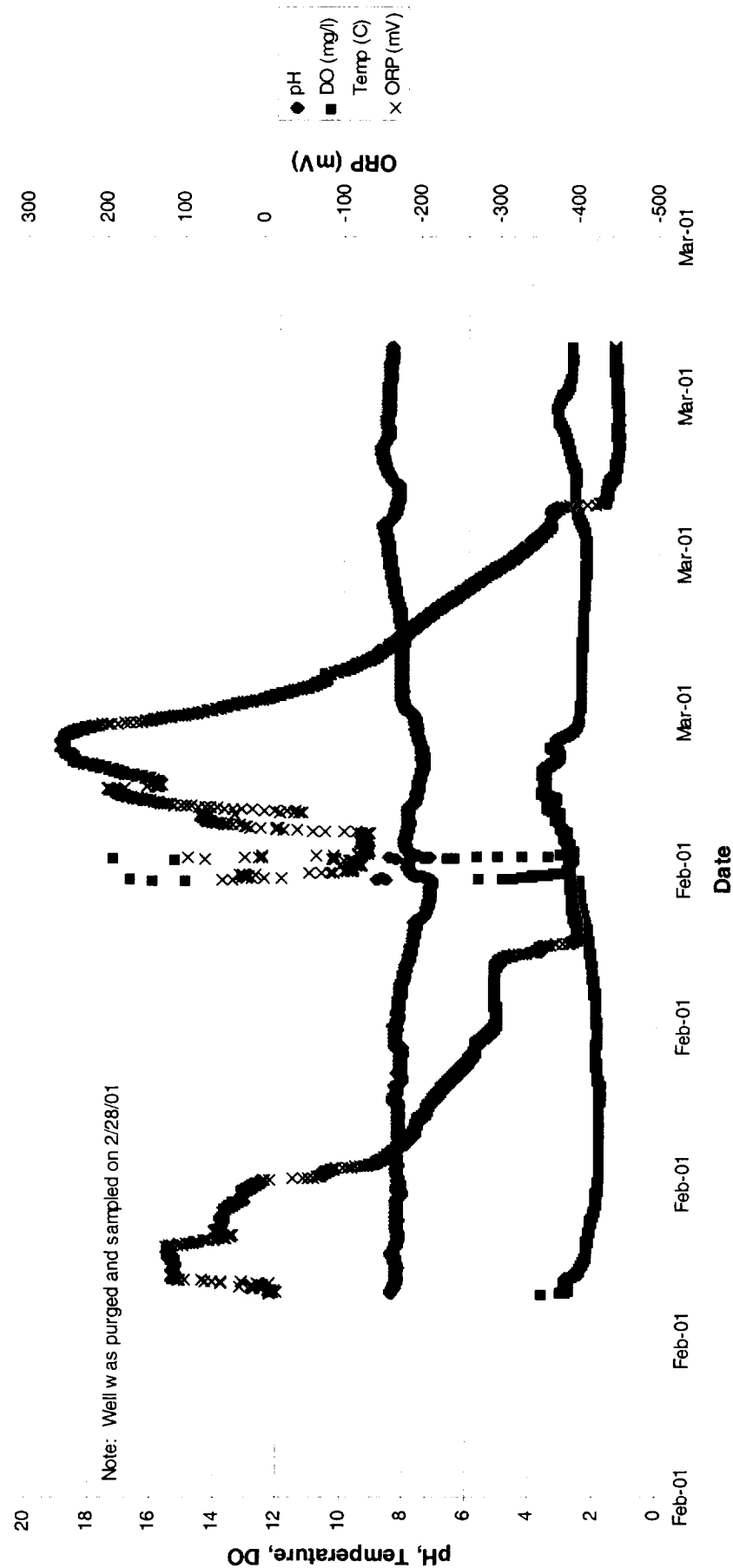
Average fracture propagation pressure was 60 psi



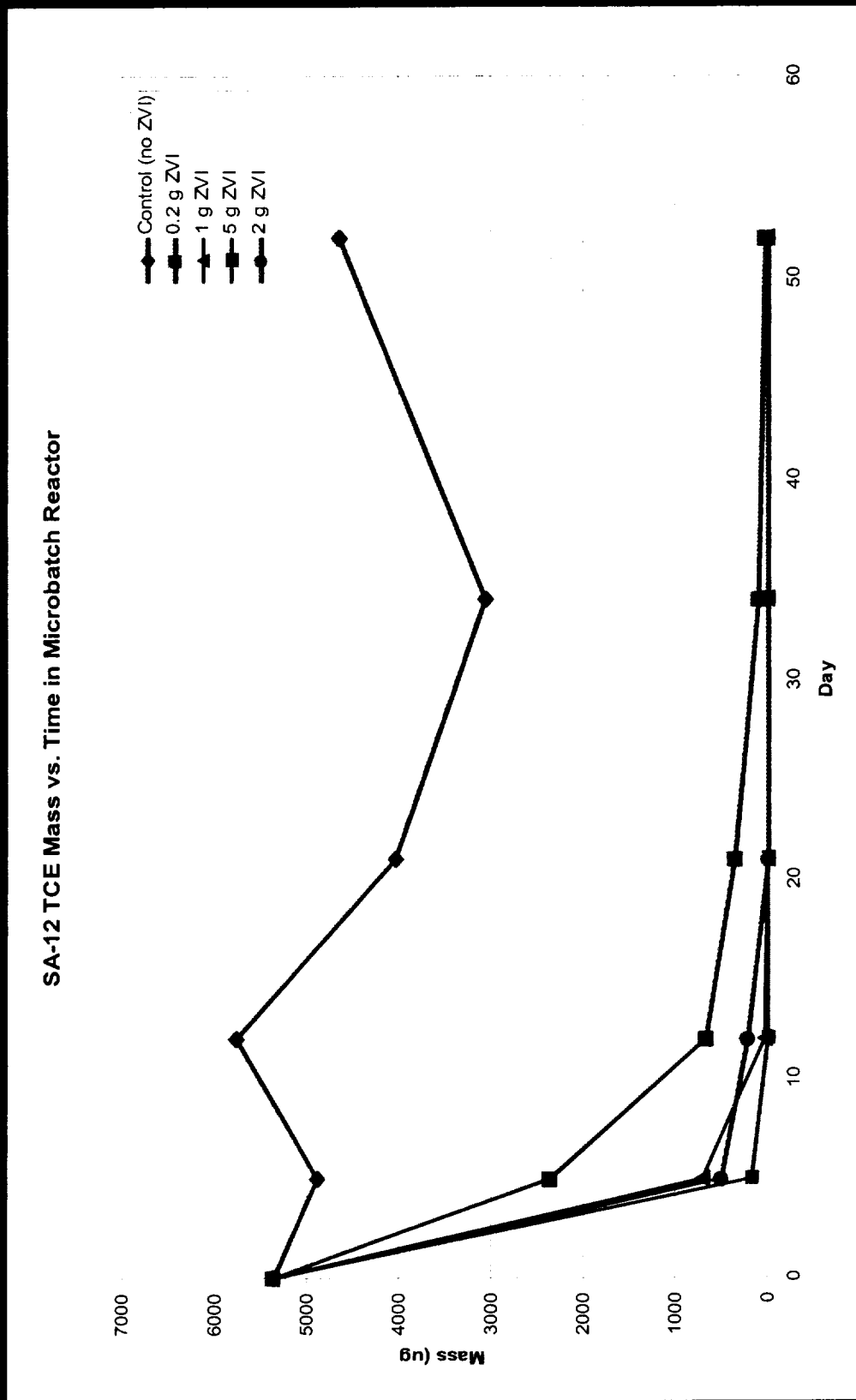
Source Area 12 Pilot Test Results - TCE Reduction



In-Situ Troll Data MW00-305

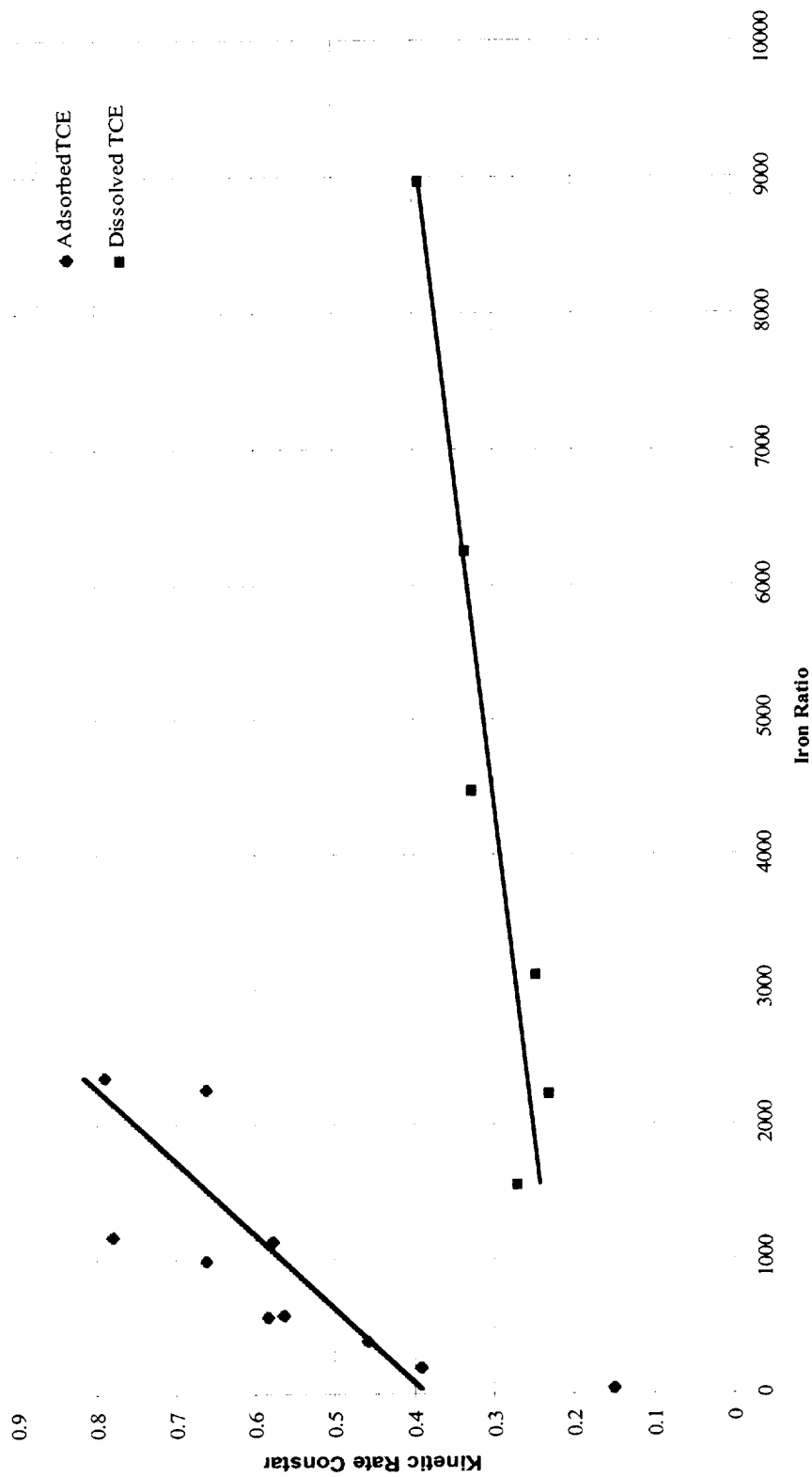


Source Area 12 TCE DNAPL Bench Scale Results



Source Area 12 TCE DNAPL Bench Scale Results (continued)

Comparison Between Rate Constants vs Weight Ratios for Contaminants Partitioned to the
Groundwater and Soil Phase



Source Area 13 Pilot Test

SA-13 Characteristics

SA-13 is located in the Northwest portion of MSFC

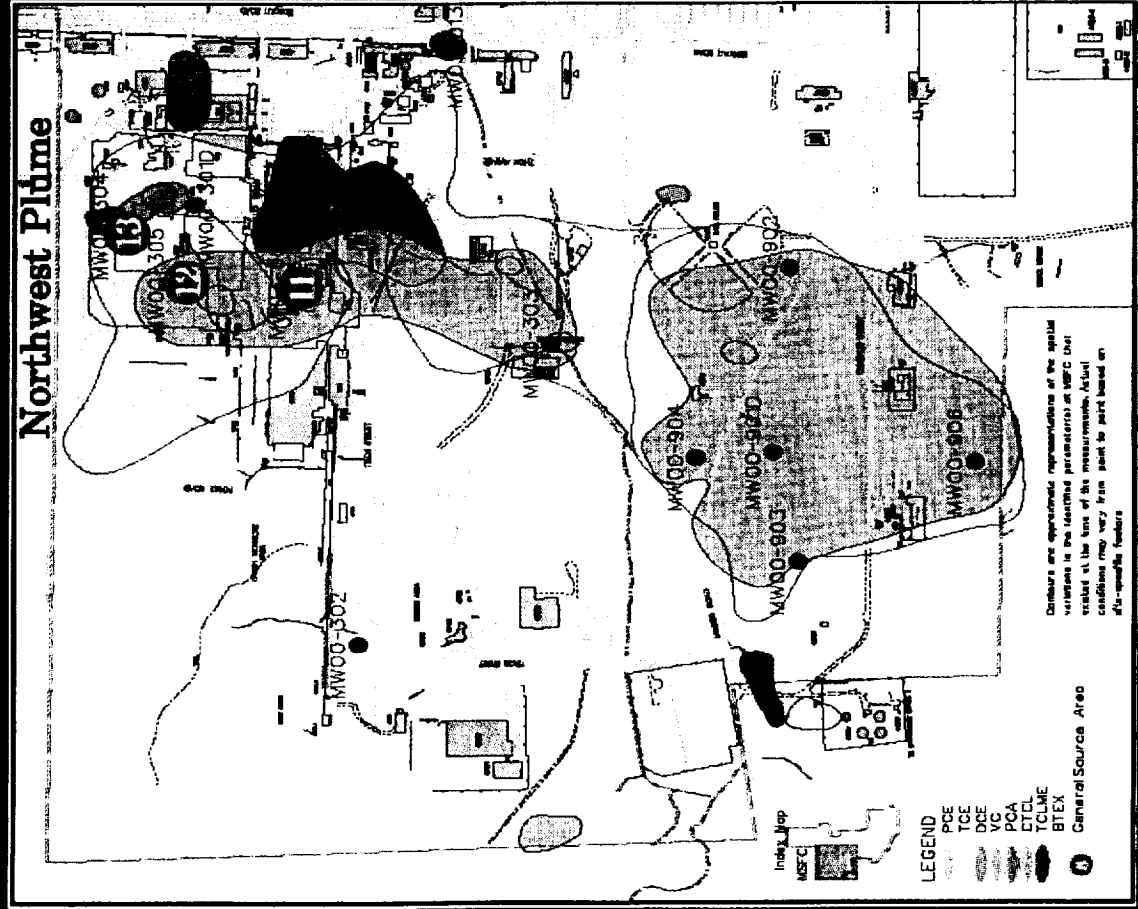
Depth to bedrock ranges from 33 to 37 feet

**TCE concentrations up to
300,000 µg/l**

Pilot Test Approach

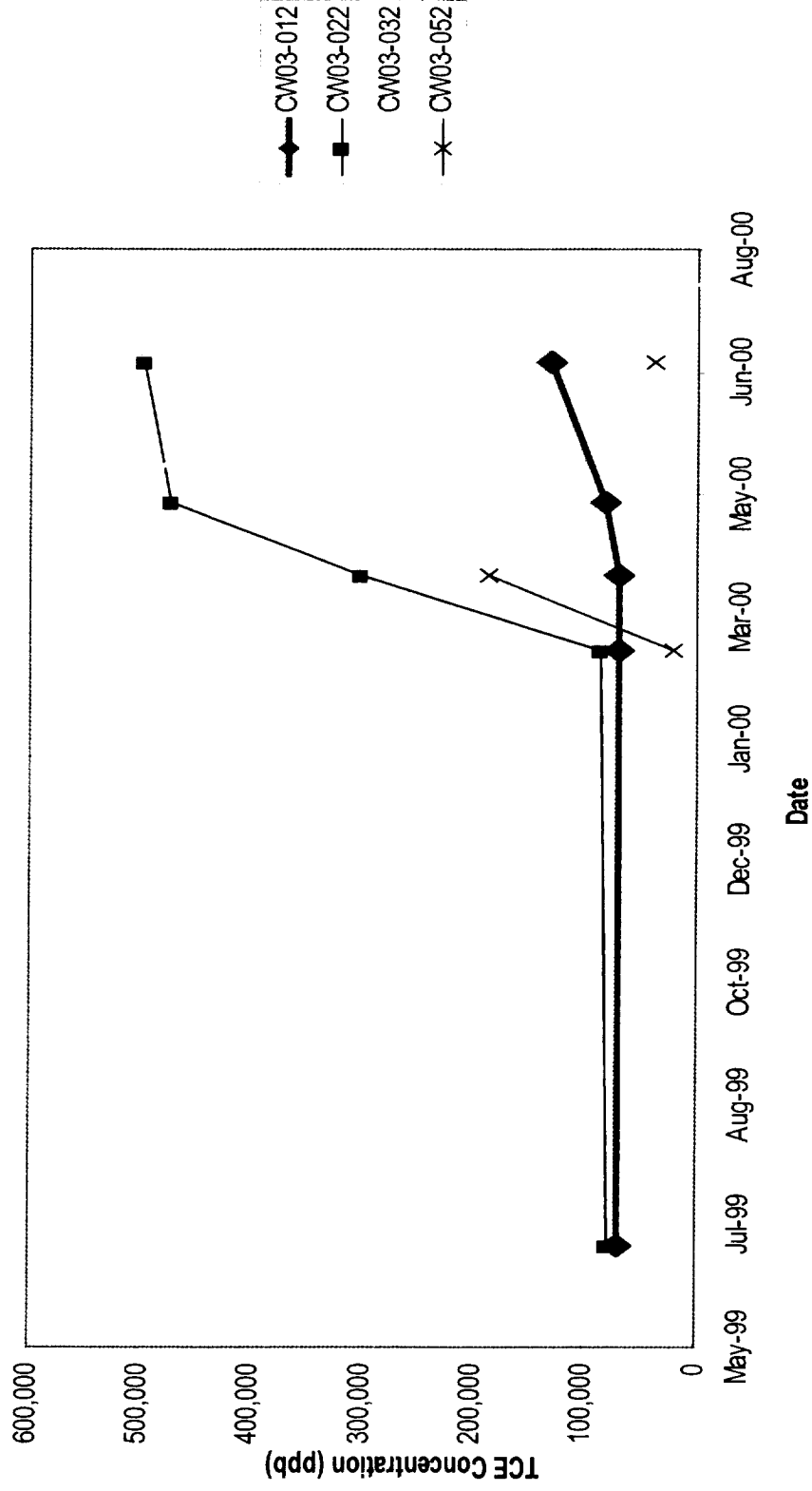
Establish a 30 ft by 30 ft treatment area

Inject Fenton's reagents in the subsurface to oxidize TCE in vadose and rubble zone



Source Area 13 Pilot Test Results - TCE Concentration

TCE vs Time in the Shallow Rubble Zone



Questions & Discussion

